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(56) Documents Cited
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GB 0623205 A
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GB 0308318 A
WO 2003/001841 A2
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(54) Abstract Title
Loudspeaker

(57) A loudspeaker is described with a frame structure 32, a diaphragm 31 and at least one electro-acoustic transducer 33 adapted to excite vibrational motions of said diaphragm, characterized in that the diaphragm has a main section 313 and at least one subsection 312 decoupled from said main section by regions of high compliance 311 and in that said transducer is coupled to said main section and said subsection.

Preferably the electro-acoustic transducer is piezoelectric.

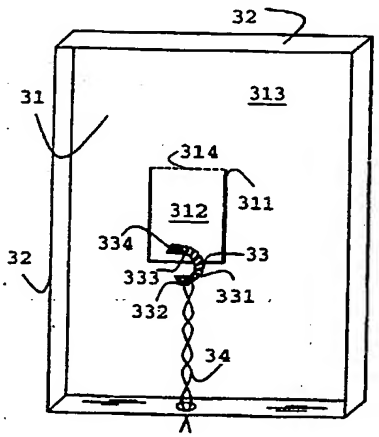

FIG. 3A

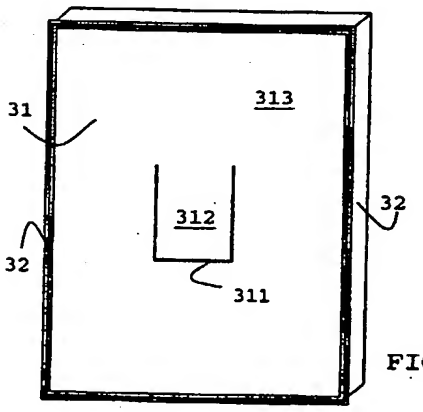

FIG. 3B

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

This print takes account of replacement documents submitted after the date of filing to enable the application to comply with the formal requirements of the Patents Rules 1995

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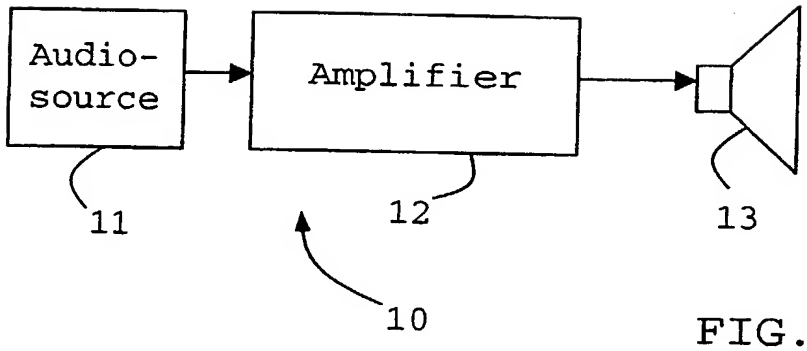

FIG. 1

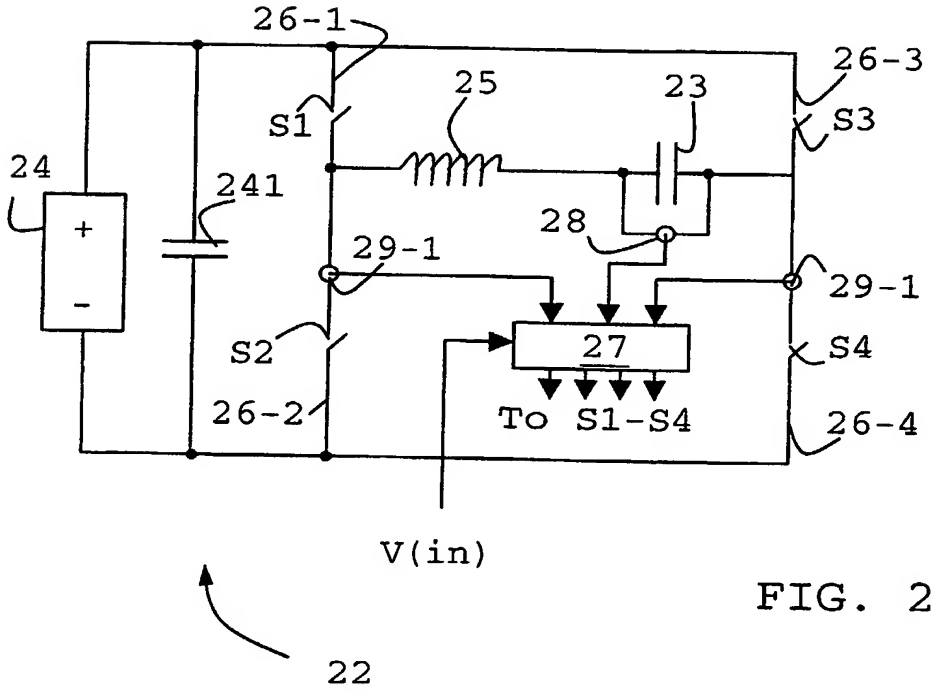

FIG. 2

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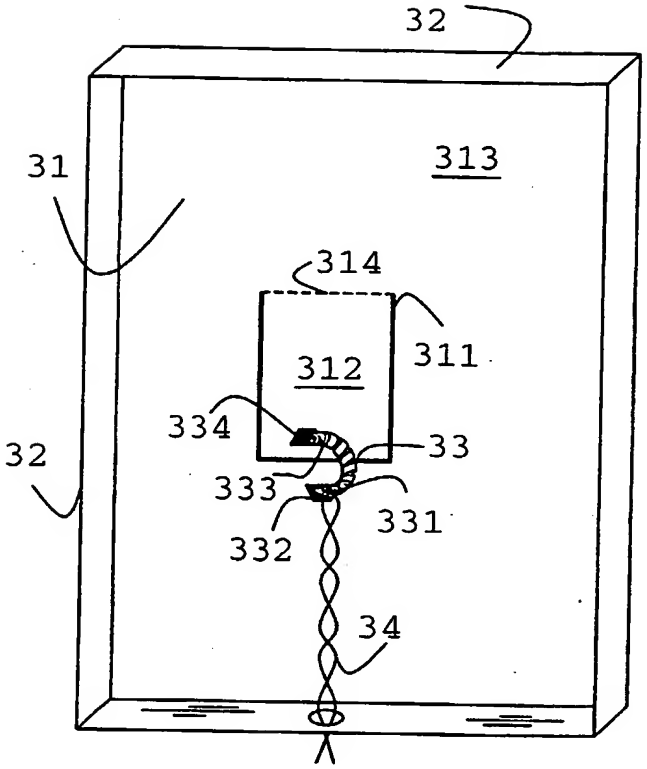

FIG. 3A

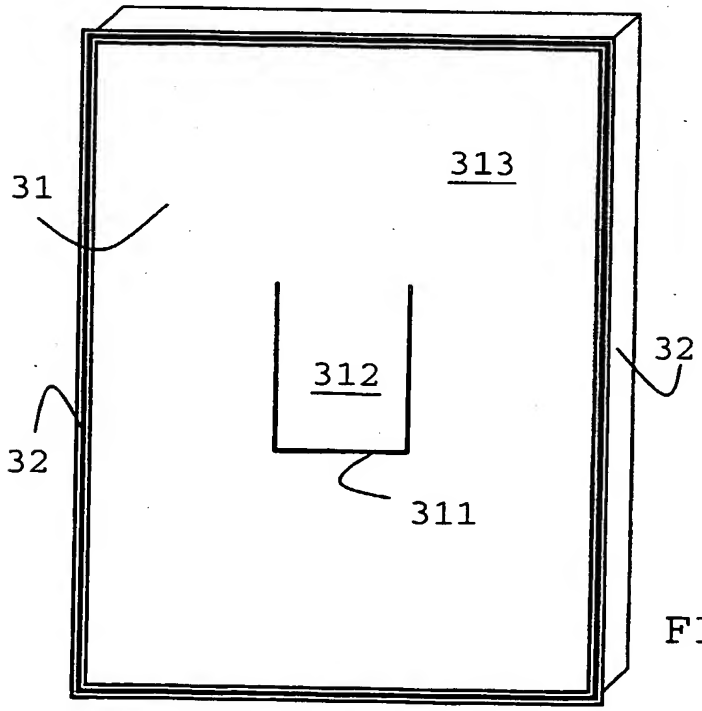

FIG. 3B

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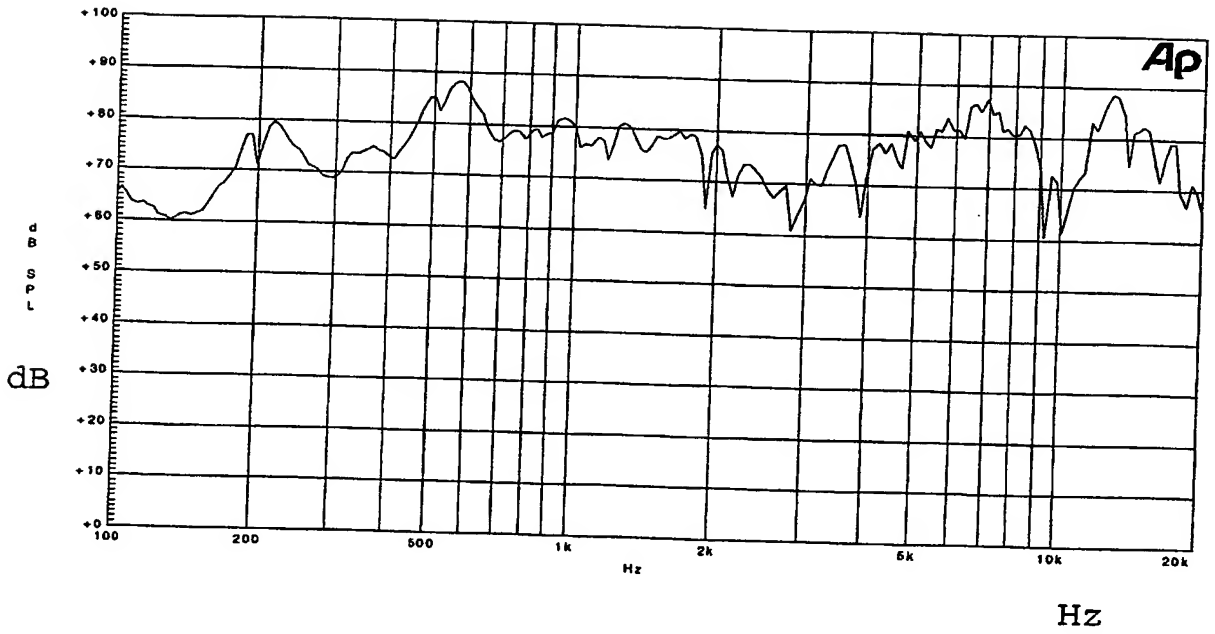

FIG. 4

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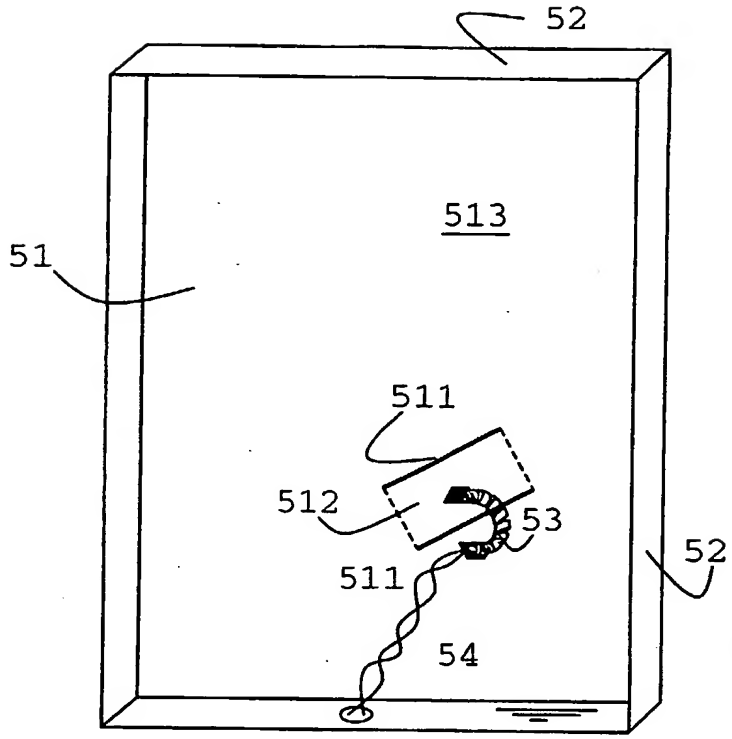

FIG. 5A

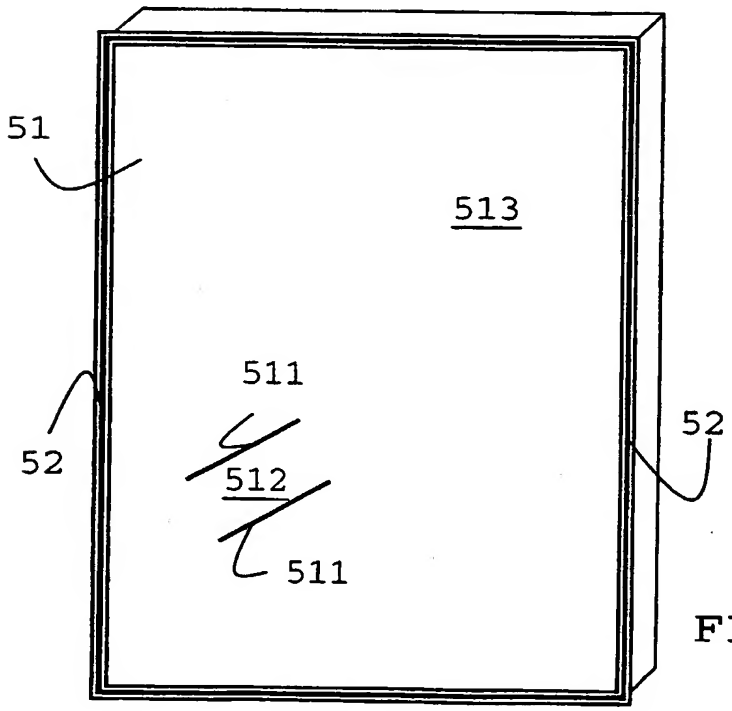

FIG. 5B

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LOUDSPEAKER

FIELD OF THE INVENTION

The present invention relates to loudspeakers, particularly loudspeakers suitable for generating audible sound of HiFi quality. More specifically, it relates to planar loudspeakers. Even more specifically it relates to planar loudspeakers having a sound generating element or diaphragm with an electro-mechanical transducer mounted thereon.

BACKGROUND OF THE INVENTION

The reproduction of audio recordings has been until very recently dominated by voice-coil driven cone-shaped diaphragms mounted on boxes or similar enclosures. Alternative technologies using planar loudspeakers have been struggling to become more wide spread either due to high costs, as, for example electrostatic loudspeakers, or due to the poor quality of the sound generated. Particularly, piezoelectrically driven loudspeakers have been almost exclusively used for low sound quality devices, such a greeting cards, buzzers, telephone speakers and the like.

Planar and piezoelectrical loudspeakers are described in many prior art documents including United States patent no. 4,654,554, the published international patent application WO-9203024, and the United States patent nos. 5,514,927; 5,780,958; 5,736,808; 6,078,126; 6,091,181 and 6,198,206.

One of the reasons that apparently hinders a wider acceptance of planar loudspeakers and piezoelectrically driven loudspeaker for HiFi applications is the insufficient reproduction of low-frequency or bass sound. Therefore it is common practice to augment flat loudspeakers (with the

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exception of electrostatic speakers) by additional woofers or sub-woofers based on the conventional loudspeaker design.

Therefore it is seen as an object of the current invention to improve loudspeaker, particularly loudspeaker for HiFi applications. It is seen as another object of the invention to improve piezoelectrically loudspeakers and planar loudspeakers.

SUMMARY OF THE INVENTION

According to a first aspect the invention provides a loudspeaker comprising a frame structure to support an extended planar diaphragm having a subsection at least partly mechanically isolated from a main section through regions of high mechanical compliance and an electroacoustic transducer mounted between the sub-section and the main section, thereby in operation generation a sound-emitting motion of both section.

The diaphragm is a membrane that when excited at frequencies in the audible range, ie. between 20 Hz and 20 kHz, is capable of vibrating at essentially the same frequencies thus generating a pressure wave in the air.

Regions of high compliance define the subsection or subsections. Hence, the subsection does not extend in a homogenous way into the main diaphragm. An alternative definition of the subsection could be that of the four rays formed by two orthogonal lines in the plane of the diaphragm intersecting in a point of the subsection at least two will traverse regions of high compliance. However, preferably the subsection and main section lie within the same plane which may be flat or curved.

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Thus, it is perceived to be easier to form both, subsection and main diaphragm, out of the same base material, it is readily feasible to use different materials in order to optimise the performance of the loudspeaker.

High compliance is understood to exert a lower restoring force on the subsection when moved away from its equilibrium position than when coupled through region formed of base material of the diaphragm.

The regions of high compliance may be provided by thinning the base material of the diaphragm, by replacing the base material of the diaphragm with a material that is more deformable, or by cutting the base material in an appropriate manner. The shape of the regions is to a large extent a matter of selection and optimisation done in connection with the choice of diaphragm materials, taking preferably the form of a straight-, piecewise straight-, or curved line or a combination thereof.

The electroacoustic transducer is preferably an actuator formed of electro-active material, in particular piezoelectric material. The transducer is rigidly coupled to a point within the subsection and to a point within the main section of the diaphragm. Hence, the transducer is adapted to displace one edge of the compliant region relative to another edge of the compliant region and out of its equilibrium position or, in other words, out of the local plane of the diaphragm.

The actuator can be solely mounted onto the diaphragm with load bearing support by the frame structure. In this case, no forces are transmitted to the frame and the forced motions of

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the two points coupled to the transducer are in antiphase as the one force is the reactive force of the other.

Though potentially various designs of piezoelectric transducer may be suitable for the purpose of the present invention, the benders described, for example, in the international patent application WO-0147318 are particularly well suited for this application which demands a large displacement of the actuator in order to generate a high sound pressure levels.

The diaphragm is best made from materials that are stiff but light.

By choosing the appropriate materials and transducers geometries, loudspeaker comparable in dimension with framed pictures can be manufactured.

These and other features of the inventions will be apparent from the following detailed description of non-limitative examples making reference to the following drawings, throughout which like parts are designated by like reference numerals and characters.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1 is a block diagram of a sound reproducing system;

FIG. 2 is a diagram of driver circuit for capacitive loads;

FIGs 3A,B show a perspective back and front view of a loudspeaker in accordance with a first example of the invention;

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FIG. 4 is a measurement of the frequency response of the loudspeaker of FIG. 3; and

FIGs 5A,B show a perspective back and front view of a loudspeaker in accordance with a second example of the invention.

DETAILED DESCRIPTION

In FIG. 1 there are shown the most important elements of a sound reproducing system 10 including a source 11, such as a CD player, an amplifier 12 and a loudspeaker 13. The loudspeaker 13 is representative for any number of loudspeakers, e.g., two for normal stereo reproduction or five or six for surround-sound reproduction.

Sound signals or data are transmitted from the source 11 to the amplifier 12 to be amplified to a level sufficient to drive the loudspeaker or loudspeakers 13.

Amplifiers to drive voice-coil type loudspeakers are well known and available and therefore, further description of this type of amplifiers is omitted.

Amplifiers to drive capacitive loads are less frequently used in the field of audio technology. Therefore, FIG. 2 illustrates a driver for piezoelectric speakers to be described below with reference to FIGs. 3 and 4.

In FIG. 2 the circuit 22 drives a capacitive load 23. The load 23 may be a piezoelectric or other electro-active device.

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The driver includes a dc power supply unit (PSU) 24. An optional reservoir capacitance 241 is provided in parallel with the PSU 24.

The driver circuit 22 includes an inductor 25 in series with the load 23. Accordingly, charging and discharge of the load 23 occur through the inductor 25. The inductance of the inductor limits the rate of change of the charge and discharge currents.

The driver 22 further includes a bridge arrangement of four switched paths 26-1 to 26-4 around the series arrangement of the inductor 25 and the load 23. The switched paths 26-1 to 26-4 together constitute a bipolar charging circuit for charging the load 23 from the PSU 24 and also a discharging circuit for discharging the load 23. The four paths includes switches S1 to S4 for opening and closing the respective paths.

The switches S1 to S4 may be any suitable types of switches, e.g. transistors, thrysistors or triacs or even relays. The switches S1 to S4 are each controlled be a controller 27, opening and closing the charging circuit and discharge circuit formed by the four paths 26-1 to 26-4.

The driver unit 22 further includes a detector 28 arranged to detect the voltage across the load 23. The second and fourth path 26-2 and 26-4 are provided with current sensors 29-1 and 29-2 for sensing the charging and discharge current flowing into and out of the load 23.

The controller switches the switches S1 to S4 and thus the capacitive load depending on the signal input voltage V(in) in a manner that is described in more detail in the British

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patent application GB-0108076.1, entitled "Capacitive Power Driver", by the same applicant and for further details reference is made thereto.

The driver transmits an amplified version of the input signal V(in) to the loudspeakers 13. For the present application the gain of the amplifier is set to 1:100 and drives the capacitive actuator with approximately 30 V rms.

The loudspeakers of the present invention, as illustrated in FIGs. 3A, B, which are a back view (FIG. 3A) and a front view (FIG. 3B), respectively, include a diaphragm 31 of flat ordinary cardboard material. The size of the diaphragm is 25 cm x 20 cm. A frame 32 formed by bending the edges of the cardboard by 90 degrees backward supports the outer limits of the diaphragm 31.

The diaphragm 31 has a U-shaped cut 311 that defines a subsection 312. The subsection is coupled to the main section 313 of the diaphragm 31 only at the dashed line 314 that denotes the transition area between subsection 312 and main section 313 of the diaphragm 31. In the present example the transition area is made of the same cardboard material as both sections of the diaphragm.

Also shown in FIG. 3A is a coiled tape 33 of piezoelectric material (lead zirconate titanate), itself wound into a second coil. The tape is typically a bimorph bender, having for the application in question an overall thickness of 1.12 mm and a width of 2.56 mm. The mean radius of the smaller primary winding is 2.34 mm with a pitch angle of 19.5 degrees and the radius of the larger secondary winding is 8.40 mm with a pitch angle of 9.3 degrees. The secondary winding makes 0.75 turns. The total mass of the actuator is 2.6 g. The actuator

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generates a peak displacement of 0.4 mm in direction of the axis of the secondary winding.

Further details of this type of actuator are described in the above referenced international patent application WO-0147318.

The actuator 33 receives the amplified signal through wires 34. Its proximate end 331 is rigidly connected to a base plate 332 that in turn is glued onto the main section 313 of the diaphragm 31. At its distal end 333, the actuator carries another base plate 334 attached to the subsection 312 of the diaphragm.

Accordingly, the coiled actuator bridges the cut or gap 311 between the subsection 312 and the main section 313 of the diaphragm 31.

When energized through the wiring 34 the actuator vibrates the diaphragm through active and reactive forces.

The frequency response of the loudspeaker device is shown in FIG. 4. The sound pressure level SLP is given in decibel (dB) measured at 1 m distance from the diaphragm in relation to the frequency in the range of 100 Hz to 20 kHz (in a logarithmic scale). The output of the loudspeaker remains within +/- 20 db throughout the full range of 100 Hz to 20 kHz.

The loudspeaker of the present invention can be modified in various ways. Clearly, it is possible to choose material different from cardboard for the diaphragm and the frame. Another way to tune the output of the system is to modify the shape of the subsection and hence the regions of high compliance.

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In FIG. 5A, B, showing the perspective view on the front and back face of another configuration in accordance with the invention, the subsection 512 is formed by two parallel cuts 511. Again the actuator is fixed to an area lying in the subsection 512 and an area lying in the main section 513 of the diaphragm 51.

The other elements and materials used for the example of FIG. 5 correspond to those used in the previous example and equivalent numerals denote the same or equivalent elements and parts.

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CLAIMS

1. A loudspeaker comprising a frame structure, a diaphragm and at least one electro-acoustic transducer adapted to excite vibrational motions of said diaphragm, characterized in that the diaphragm has a main section and at least one subsection decoupled from said main section by regions of high compliance and in that said transducer is coupled to said main section and said subsection.

2. The loudspeaker of claim 1 wherein the transducer comprises a piezoelectric actuator.

3. The loudspeaker of claim 2 wherein the actuator is of a coiled-coil type.

4. The loudspeaker of claim 1 wherein the transducer is exclusively coupled to the diaphragm.

5. The loudspeaker of claim 1 wherein the regions of high compliance are slits in the diaphragm.

6. The loudspeaker of claim 1 wherein the diaphragm is planar.

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Application No: GB 0204716.5
Claims searched: 1 to 6
Examiner: Peter Easterfield
Date of search: 20 May 2003

Patents Act 1977 : Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance	
X	1-3,6	WO 03/001841 A2	(1...) see figs 6-9
X	1	GB 0665815 A	(MARCONI)
X	1	GB 0623205 A	(STANDARD TELEPHONES)
X	1	GB 0311486 A	(BRITISH THOMSON-HOUSTON)
X	1	GB 0308318 A	(MARCONI)
A		WO 98/52381 A1	(NEW TRANSDUCERS)

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC[V]:

H4J

Worldwide search of patent documents classified in the following areas of the IPC[7]:

H04R

The following online and other databases have been used in the preparation of this search report:

WPI, EPODOC, JAPIO

An Executive Agency of the Department of Trade and Industry

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